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South-to-north water diversion project

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RESEARCH ON HYDRAULIC OPERATION SYSTEM
SOUTH-TO-NORTH WATE

BY GAO JIZHANG AND CHEN WENXUE

China's South-to-North Water Diversion Project (SNWDP) is a major strategic infrastructure aimed at easing severe water shortage in North China and optimizing water resources allocation. General layout for SNWDP has been worked out as three water transfer sub-projects, i.e. the Eastern Route, Middle Route and Western Route, which are to divert water from the lower, middle and upper reaches of the Yangtze River respectively.

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The Middle Route Project (MRP), diverting water by gravity flow in open canals, starts from Danjiangkou Reservoir in Hubei Province and finally reaches Beijing and Tianjin. It goes through quite urbanized regions in Hubei, Henan, Hebei Provinces, and Tianjin and Beijing Municipalities, altogether crossing a dozen of medium-large cities and over 100 counties and towns. The main channel of the MRP is 1432km long and diverts 13 billion m3 to 14 billion m3 of water in annual average.

The MRP has over 1790 hydraulic structures: over 160 river-canal crossing structures (including the Yellow River Crossing Project), over 490 left-bank drainage structures, over 130 canal-canal crossing structures, over 40 railway-crossing structures, over 730 over-canal bridges, over 80 water diversion outlets, over 60 check gates, over 50 wasteway gates, 2 exit gates, nearly 30 deicing gates, 8 retaining weirs, 3 overflow weirs, 9 tunnels and 1 pump station. Among them there are over 270 real time regulation structures, including water diversion outlets, check gates, outlet gates, wasteway gates, outlet control gates of inverted siphon and pump station.
The significant number of hydraulic structures along the MRP, coupled with varied geological and climate conditions, confront the hydraulic operation system with many technical challenges, such as water diversion in freezing periods. Chinese researchers have risen to these issues with various researches over the decade. This paper briefly introduces some results on the hydraulic operation control of the main canal.

Development of the hydraulic operation method of the MRP
The main canal of the MRP is designed to operate under constant downstream water depth for reducing construction costs. When the flow rate is to be changed, the requirement of the storage volume in the canal pools is contrary to the change tendency of the storage volume. The response of the hydraulic operation system is consequently slow. In order to increase response speed and shorten the response time of the operation system, a distributed control algorithm combining a feedforward control loop, a feedback control loop and an upstream

Layout of MRP

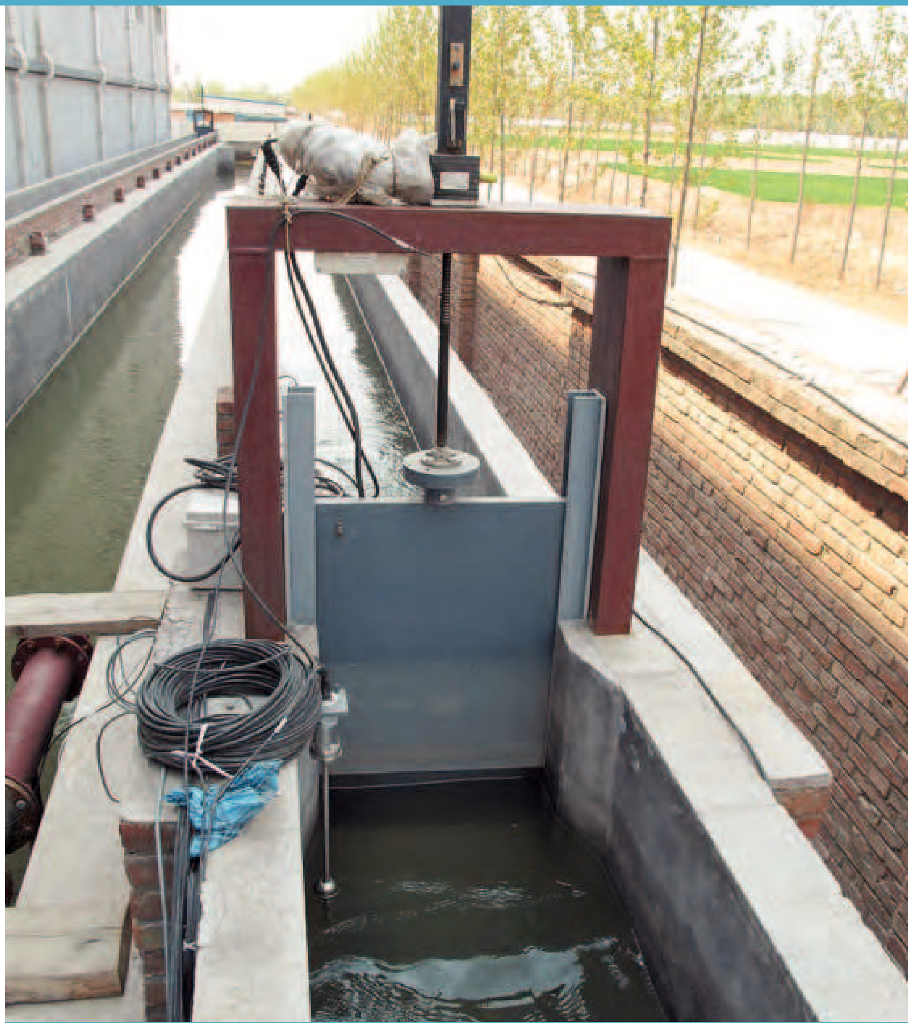
OF THE MIDDLE ROUTE PROJECT OF CHINA
R DIVERSION PROJECT

decoupler is devised. The feedforward control is to determine the controlled flow through each gate based on the demand delivery and the delay time of the canal pools; The feedback control is aimed at maintaining the constant water depth by eliminating the impact of known and unknown disturbances; and the decoupler is aimed at eliminating the coupling effects among canal pools and shortening the transition time for the canal. Such a threefold algorithm can effectively speed up the system response, hence laying the groundwork for diverting water in ten-day's allotment.

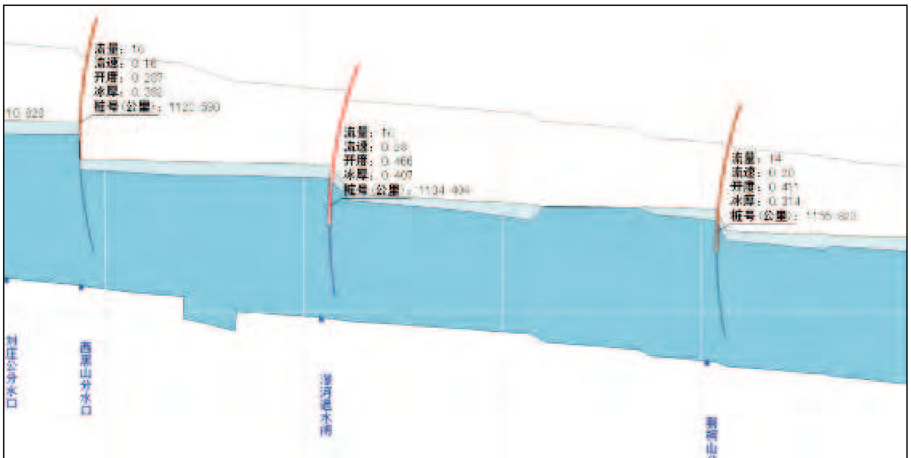
The feedforward control loop uses an improved volume compensation method. Different from the original one put forward by Bautista et al., the improved volume compensation method allows for variances in feedforward control time, which is determined by not only the flow of turnouts, but also the constraints of the canal systems, such as the drawdown rate of the canal pools and fluctuation range of the water level.

The feedback control loop uses a water level-flow cascade control that, when compared with the traditional method, can quickly eliminate the impact of disturbances on the system, reduce operation frequency of check gates and restrain water level fluctuation. This kind of control method also has decoupling effect on the downstream canal, since the flow rate of the check gates can maintain constant despite upstream disturbances.

A control algorithm for the system operation under the variant downstream water level is also developed, since the water level at the upstream of the check gates will be changed such as in the freezing period. This algorithm consists of the ordinary algorithm mentioned above and a volume compensation algorithm considering the variance in water depth. Therefore, the presented algorithm can not only deal with the canal system operated under the constant downstream water depth, but that under the variant downstream water depth also.



Canal model in IWHR



Ice simulation of MRP

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Research on safe water diversion in freezing period

The canal systems in high latitude areas are usually operated under ice cover during winter time, because the ice cover's heat insulation can avoid further formation of ice floes in the water under the cover. The MRP, especially the canal pools at the north of the Yellow River, will be operated under ice cover also. Various control measures are developed in order to avoid ice jam and ice dams and guarantee safe water transfer during freezing period. They include:

1) Control Froude number at each flow cross-section below the second critical Froud number of 0.08, beyond which floating ice will submerge at the edge of the ice cover or the ice boom and ice jam may be formed. Controlling Froude number helps ensure ice cover will be formed smoothly. The maximum water diversion capacity in the freezing period in the main canal of the MRP does not exceed 50% of normal diversion capacity.

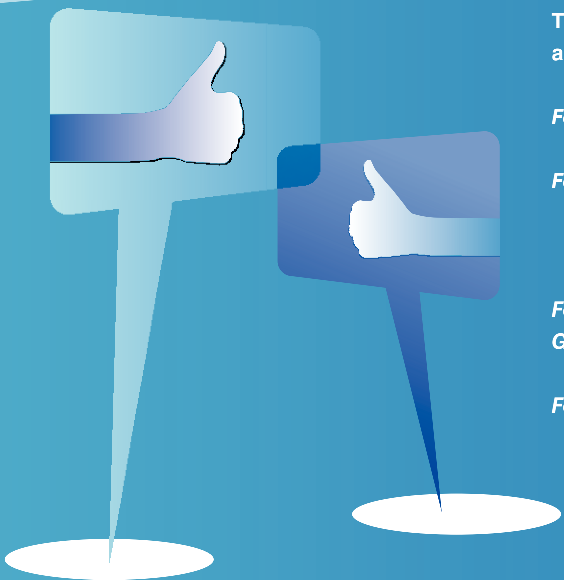
2) The canal system should be operated under constant downstream water depth. During formation of the ice cover, floating ice will build up before the ice boom and the ice cover will be formed at the end of the canal, and then extend upstream. The composite roughness along the canal will be increased during the forming of the ice cover, and the storage capacity of the canal pools will be increased also since the flow rate of the canal pools should be kept constant. At the same time, the water surface profile of the canal pools will pivot around the ice boom. Therefore, the operation method of the canal system with constant downstream water depth will be favorable to the formation of the ice cover.

3) A water level-flow cascade feedback control algorithm should be used during the freezing period of the canal system. During the formation and break-up of the ice cover, the water level and the flow rate will be changed because of the variation of the composite roughness of the canal system, and ice jam or ice dam may be formed if the operation of the canal system is not controlled properly. Numerical simulation reveals that when the water level-flow cascade feedback control algorithm is applied during the freezing period, the maximum fluctuation range of water level near the check gates is $\pm$10.0cm, and maximum water level fluctuation is about $\pm$10.6cm/day, hence the stability of ice cover could be achieved, and it is also favorable to the ice cover melt in situ.

4) Ice booms are erected in front of inverted siphon and check gates. A net-style ice boom is developed for better ice stopping effect. This new ice boom is highly stable and can facilitate the formation of ice cover, thus helping water transfer under the ice cover.

The Middle Route Project of SNWDP faces many technical challenges. The research results aforementioned in this paper have yielded benefits in supporting the sound hydraulic operation of the Project.

IAHR 2013 COUNCIL ELECTIONS: SLATE OF CANDIDATES



The 2013 Nominating Committee chaired by Prof. Nobuyuki Tamai has completed its work and proposes the following slate of candidates for the Council elections to be held in July:

For President: **Roger A. Falconer**

For Vice President: **(Asia and Pacific): Zhaoyin Wang**
(Europe): Philippe Gourbesville and Arthur Mynett
(North & South America and Others): Marian Muste

For Secretary General: **Ramon Gutierrez Serret**

For Council: **(Europe): Michele Mossa, Anton Schleiss, Hovhannes Tokmajyan, Damien Violeau and Silke Wieprecht**
(Asia and Pacific): James Ball, Jing Peng, Hitoshi Tanaka and Hyoseop Woo
(North and South America and Others): Angelos Findikakis and Arturo Marcano

According to the By Laws IAHR members may also propose additional candidates "by petition" for the post of Council Member, independently of the Nominating Committee. For more information see the IAHR website.

The deadline for submitting such petitions is June 1st. Please send your nominations to Elsa Incio at membership@iahr.org